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DESIGN OF MONORAIL SYSTEMS FOR MOORING IID7 TETHERED BALLOONS.(U)
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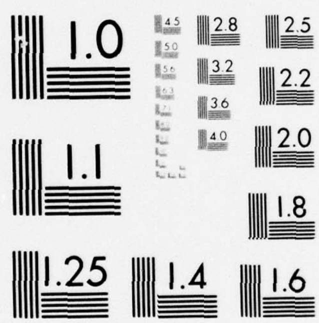

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TELTA REPORT NO. TR 71-016

TECHNICAL REPORT

DESIGN OF MONORAIL SYSTEMS

FOR

MOORING IID7 TETHERED BALLOONS

1 December 1971

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Monorail Mooring System
Gondola

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The static mass and buoyancy measurements of IID7 balloon 201, recently measured under simulated flight conditions reveal a net trim situation which vitiates the use of a payload service gondola for mooring. The mast/monorail mooring system is discussed as a mooring system for the IID7 balloon. Designs for monorail systems at Cudjoe Key are described and cost/schedule estimates are given.

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TELTA TR No. 71-016

DESIGN OF MONORAIL SYSTEMS

FOR

MOORING IID7 TETHERED BALLOONS

1 December 1971

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ABSTRACT

The static mass and buoyancy measurements of IID7 balloon 201, recently measured under simulated flight conditions reveal a net trim situation which vitiates the use of a payload service gondola for mooring. The mast/monorail mooring system is discussed as a mooring system for the IID7 balloon. Designs for monorail systems at Cudjoe Key are described and cost/schedule estimates are given.

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PREFACE

A monorail mooring system is one of several methods of mooring an inflated aerodynamic-shaped balloon when it is not flying on its tether. The general elements of this system are a mast with a masthead having rotational freedom in azimuth, to which the balloon nose is attached, and a circular track upon which rides a captive truck or trolley, to which, in turn, is attached a confluence of the balloon's mooring lines. The track radius is chosen so that the mooring confluence point is approximately at the pitch-balance of the balloon and little or no static vertical force is imposed on the tower. The swiveling masthead and circumvolving trolley permit the balloon to always head upwind which is the desired, minimum-stress condition.

The frontispiece is a photograph of a BJ + 3 type of balloon (T/N 71) moored on its monorail at Cudjoe Key AFS.

STATEMENT OF PROMULGATION

This report was prepared in direct response to the request for same made by ENL/ENLT in a conference presentation on the same subject held at RML on 5 November 1971.

I. Scope

This document is a preliminary design study on monorail mooring for the IID7 type balloon. It is the response to a request from ENLT on 5 Nov. 71. Because of the very short preparation time, it will not be possible to describe all features of the system in ultimate detail. However, all of the principal features will be described and all of the more sensitive determinants of operational feasibility, dimensions, and safety will be given.

II. Purpose

This paper is intended to present sufficient information as to permit ENLT and TELTA to make committing decisions to use monorail moorings for IID7 balloons at Cudjoe Key and/or CKAFS, specifically, and to decide with confidence as to the suitability of this type of mooring system for any other application of the IID7.

III. Introduction

The first IID7 balloon, designated 201, is the first IID7 balloon to have been manufactured. Technical difficulties involving tailoring and adhesives have delayed the performance of normal inflation tests until the past week. The results of these tests have confirmed quantitatively and accurately the earlier indications that V/N 201 when rigged for flight, but less payload, will be pitch-balanced when tethered at BS (X) = 25.56 feet with tether stress of about 3600 pounds, static. The gondola, centered at about BS-55, and mass-trimmed for neutral buoyancy, results in an unacceptibly high load on the tower. Even if this were of no concern, this nose-up characteristic makes mating the balloon to the tower operationally impossible without using a weight of about 700 pounds near the balloon nose.

To obviate the need for the nose weight, a relatively heavier gondola (greater than 3000 pounds) may be attached to a point some 20 feet forward of the presently proposed location ($C_m \cong 55$); but such a structure would be positioned well away from the payload area and could, hence, not serve as a payload service vehicle.

A second generation gondola is planned for design committment in the near future. The burden of this paper is not to advocate the monorail in preference to the gondola, but rather to present the essential practical information on a monorail system to moor the IID7 balloon.

The first essential is a description of the relevant weight and balance properties of the balloon which implicitly define the mooring requirements.

NOTE: The discussion will be constructed from the measured characteristics of hull 201 carrying serial 202 fins, as presently contemplated for the first flight of the IID7 series.

IV. Aerostatic Characteristics of HN201-F202

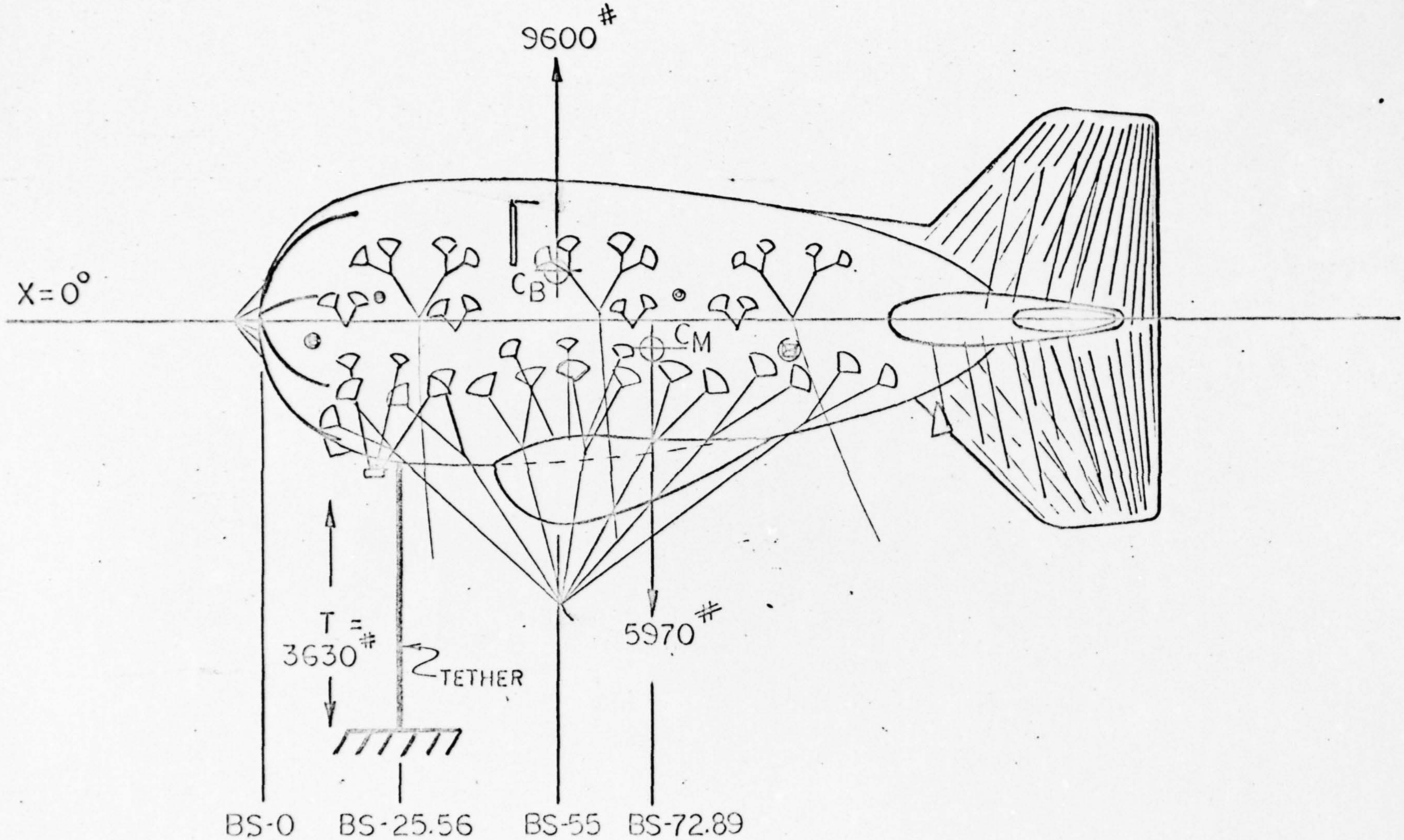
The simplest method of showing the mooring requirements is illustrated in Figure 1. In this diagram, shown approximately to scale, the IID7 is rigged for flight with all hardware mounted except for payload, windscreen, and power-plant fuel load. The balloon exerts no force on the tower and its pitch trim angle is zero degrees and this pitch attitude is equilibrium. It is seen that its buoyant force is 9600 pounds at body station 55, ten feet above the midline. Its mass center is about 73 feet aft of the nose and about 5 feet below the midline. The tether tension is 3630 pounds, applied about 25.5 feet behind the nose. (All measurements are from the fabric nose, not the structural accessories, although these are mounted.)

V. Mooring System Design

A. Balloon Subsystem; from the confluence point, up.

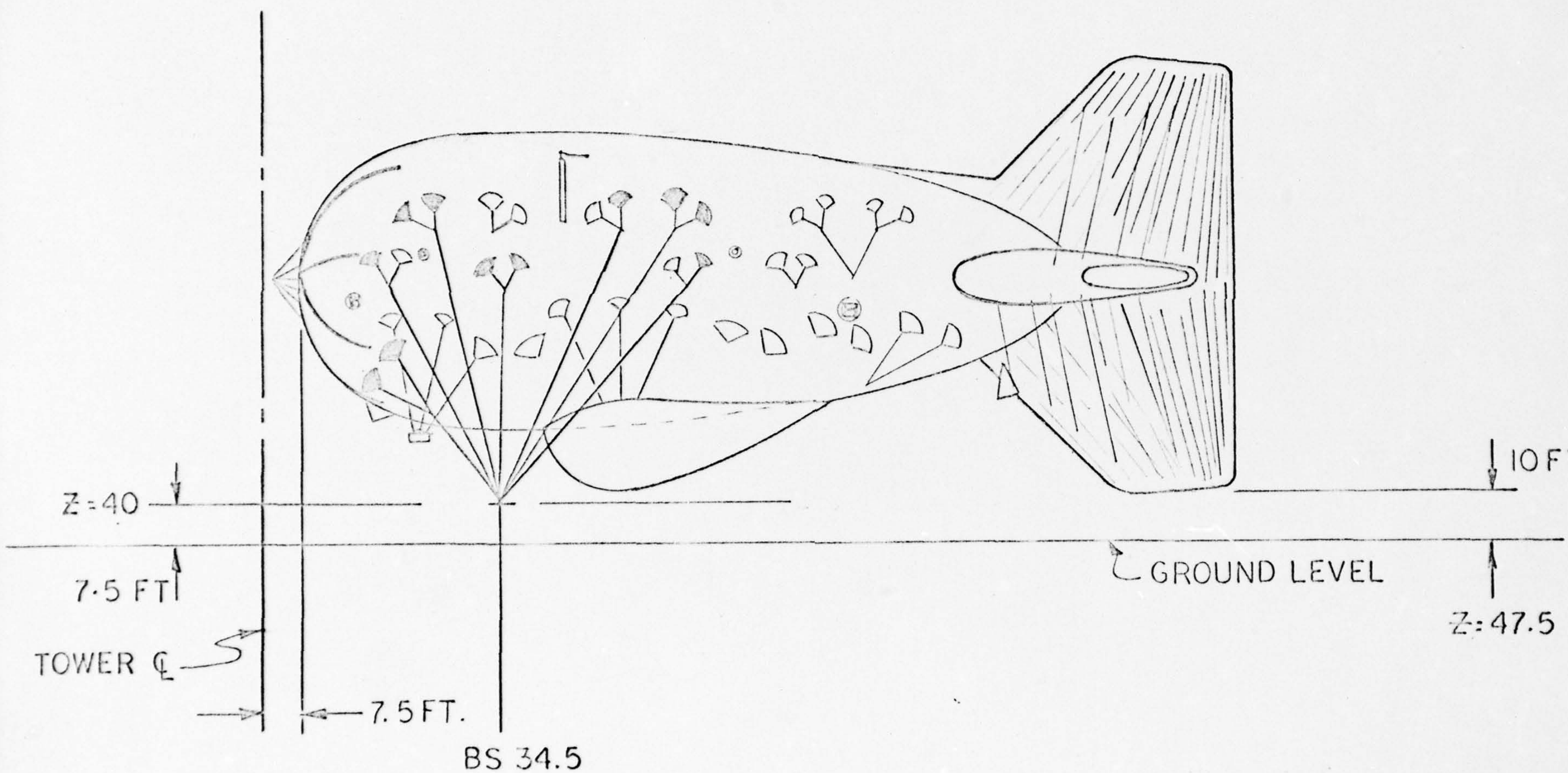
In the diagram of Fig. 1 it can be seen that movement of the tether point forward will cause the balloon to push down on the tower; and a tether point farther aft will conversely cause the balloon to exert an upward pull on the tower. A moderate upward force is desirable for operational reasons so that a practical value for the tether point will be chosen so that a force of about 300 pounds, upward, is produced.

In Fig. 1, the tether was shown schematically as a single line located at the body station corresponding to mooring equilibrium. The actual attachment of the mooring cable to the balloon is made via an array of cables so as to distribute the tether stress into a substantial area of the hull fabric. Fig. 2 shows the arrangement proposed for the mooring confluence lines.



MOORING FORCES & CTRS, IID7
RIGGED FOR FLIGHT, LESS P/L, W/S & FUEL

FIG. 1



MOORING CONFLUENCE RIGGING

FIG. 2

As seen in Fig. 2, eleven patches are used. Four patches are auxiliary patches and are not otherwise used during flight or mooring. They are one-ton patches. Three of the remaining patches are from the quad set intended for the middle closehaul bridle and are one-ton patches. This closehaul set is not used otherwise, since the fore and aft quad sets are more than sufficient for closehaul operations. The last four patches are the forward pair of the fore-end closehaul set, one-ton each and the forward flying confluence line set of two, two-ton patches. These latter four patches are used for closehauling and flying, respectively, but there is no operational inconvenience in using them for mooring.

As remarked earlier, the tension on the mooring tether is 3630 pounds at equilibrium. The tension at the mooring tether point at BS 34.5 will differ only slightly from this value since some of the "up" force is intentionally transferred to the tower. The patches to be used have a rated load capability of 13 tons per side or 26 tons total, static. This is 14.3 times the static load. The line recommended for rigging the mooring confluence is Samson "2 in 1 Stable Braid" as used for the flying confluence lines. See Fig. 3 for Samson published data. The 7/16" size has a break strength of 5,100 pounds and weighs 5.1 pounds per 100 ft. The total weight of the mooring confluence rigging is estimated at 34 pounds, exclusive of the spreader plate at the C-P, and the mooring tether which will probably be a stainless wire rope painter with swaged eyes. It will be about 6 ft. long and weigh about 8 pounds. The spreader plate should be a smaller, lighter copy of its flying counterpart.

The choice of the confluence point is somewhat arbitrary and 34.5 ft. was chosen as a reasonable value. It allows for 7.5 ft. between the fabric nose (BS 0), and the tower centerline, using the present nose latch. The resulting monorail radius is 42 feet. The "up" force on the tower will be somewhat more than 300 pounds but well below the 1000 pound static limit. Although it is believed possible to meet all requirements with a more forward point, BS 34.5 is on the conservative side and we feel that it is the best choice for the first installation, at least. The position of the confluence point may be trimmed slightly, in either direction.

B. Monorail Subsystem; from the confluence point, down.

From the spreader plate, the tension is transmitted to a short stainless wire rope painter to the yoke which in turn is connected at each end to a trolley. The trollies engage a six-inch monorail which is fastened to the ground.

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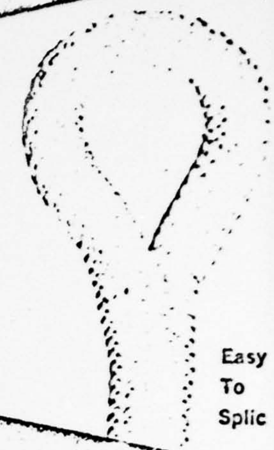

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1/4"	3/4"	1,700	1.7	10.2	$4.25	$ 7.23	$ 43.35
5/16"	1"	2,600	2.6	15.6	4.00	10.40	62.40
3/8"	1-1/8"	3,500	3.5	21	3.95	13.83	82.95
7/16"	1-1/4"	5,100	5.1	30.6	3.75	19.13	114.75
1/2"	1-1/2"	6,800	6.8	40.8	3.65	24.82	148.92
5/8"	2"	11,000	11	66	3.60	39.60	237.60
3/4"	2-1/4"	15,000	15 13.6	90	3.40	51.00	306.00
7/8"	2-3/4"	20,000	20	120	3.40	68.00	408.00
1"	3"	28,000	28	168	3.40	95.20	571.20
1-1/8"	3-1/2"	35,000	35	210	3.20	112.00	672.00
1-1/4"	3-3/4"	40,000	40	240	3.00	120.00	720.00
1-5/16"	4"	45,000	45	270	2.80	126.00	756.00
1-1/2"	4-1/2"	60,000	60	360	2.80	168.00	1008.00
1-5/8"	5"	75,000	75	450	2.80	210.00	1260.00
1-3/4"	5-1/2"	90,000	90	540	2.60	234.00	1404.00
2"	6"	100,000	100	600	2.60	260.00	1560.00
2-1/8"	6-1/2"	120,000	120	720	2.60	312.00	1872.00
2-1/4"	7"	140,000	140	840	2.60	364.00	2184.00
2-1/2"	7-1/2"	160,000	160	960	2.60	416.00	2496.00
2-5/8"	8"	180,000	180	1080	2.60	468.00	2808.00
2-7/8"	8-1/2"	200,000	200	1200	2.60	520.00	3120.00
3"	9"	240,000	240	1440	2.60	624.00	3744.00
3-1/4"	10"	275,000	280	1680	2.60	728.00	4368.00
3-1/2"	11"	315,000	320	1920	2.60	832.00	4992.00
4"	12"	390,000	400	2400	2.60	1040.00	6240.00
4-1/4"	13"	465,000	480	2880	2.60	1248.00	7488.00
4-5/8"	14"	535,000	560	3360	2.60	1456.00	8736.00
5"	15"	610,000	640	3840	2.60	1664.00	9984.00

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FIG. 3

The circular "I"-section rail is made of 48 sections, rolled to the 42' radius arc and joined by bolted plates. The plates will be anchored at Cudjoe Key by "Red-Head" fasteners, driven into the existing concrete pad, and bolts. The monorail at CKAFS will be bolted by its baseplates to fabricated anchors which will be installed in augered holes and set with concrete.

NOTE: No concrete will be necessary in the tactical case; earth-screw anchors will be used. In the special case of Pad 3A, the original intent was to make a semi permanent site and therefore poured piers are used for tower and sheave anchors and the pad area is faced with compacted marl. So in the interest of speed and permanence, the Pad 3A monorail anchors will use concrete fill in the holes.

VI. Detailed Monorail Design

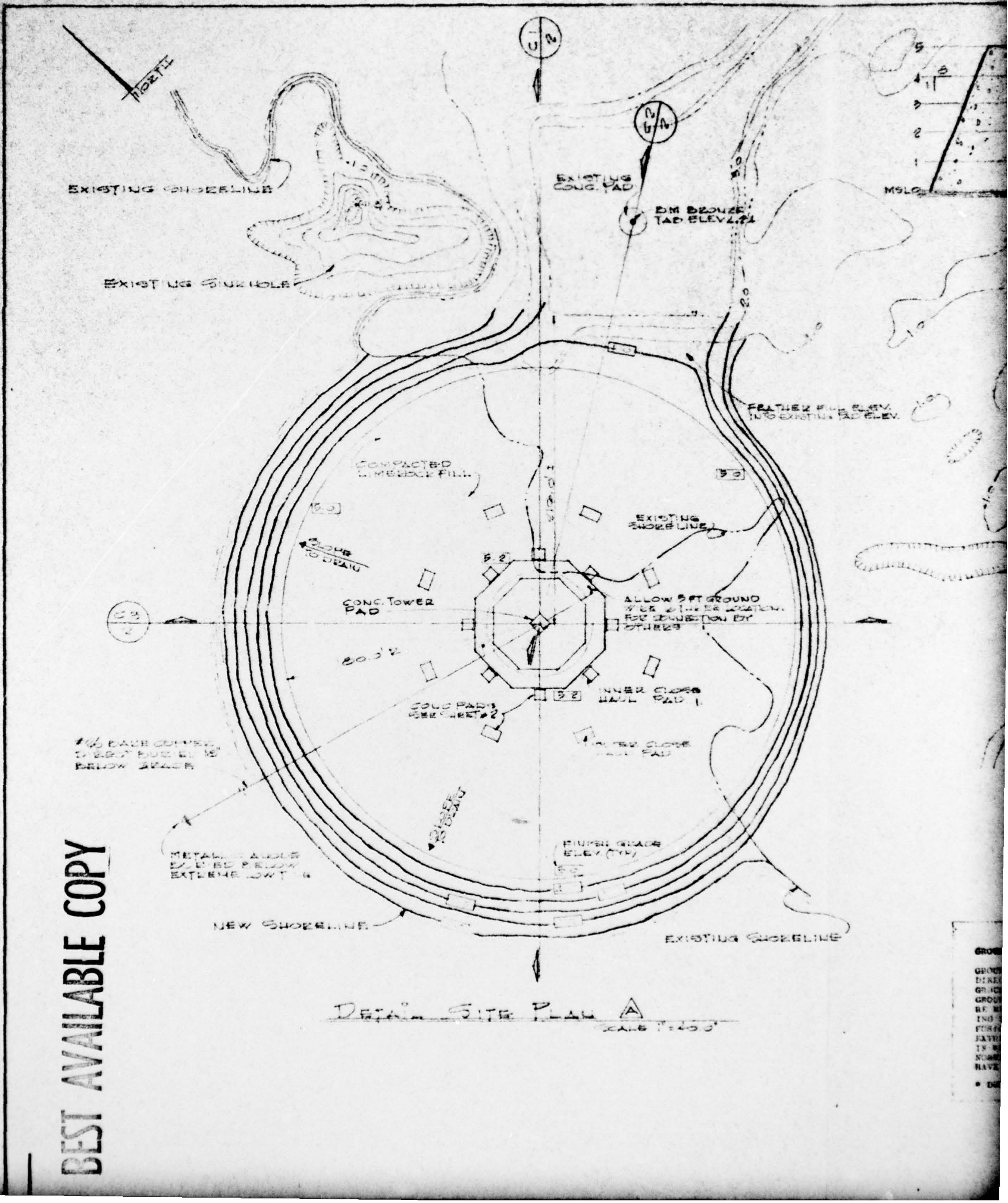
A. Cudjoe Key Site

As stated above, a 42 foot-radius monorail will be installed in the existing concrete pad. For reference purposes the plat of the Cadjoe Key site is included in Fig. 4. A larger scale drawing of the octagonal pad is shown in Fig. 5. The maximum circular radius of the pad is seen to be 45 feet; this will comfortably accomodate the 42 foot radius monorail. If future experience should justify a shorter radius, this pad will be satisfactory down to a minimum of about 33 feet.

The drawing of Fig. 6 shows the details of the mounting of the rail sections. The drawing is self explanatory. Appendix "A" gives the load/strength analysis calculations for the rail, the rail fastening plates and the "Red-Head" concrete anchors. The 6 inch "I" is a very conservative choice and the plates and hardware are well over-designed.

1. Rail Details

The rail selected is a 6 inch steel "I" section rolled to the desired arc radius. The sections are 5'5-15/16" in length and 48 are required. Each rail is assembled to a 6" X 10" baseplate at each end. A half-size baseplate, 3" X 10" is fastened at the center of each rail section. These plates are 3/4" thick mild steel, and punched to pick up the bolts which secure the rail to the pad. Additionally, two 2"X13"X1/2" tie bars per joint will join the rail sections. TELTA drawing C SK 5091 as Fig. 6 shows these details.



Detail Site Plan A

Scale 1" = 40.0'

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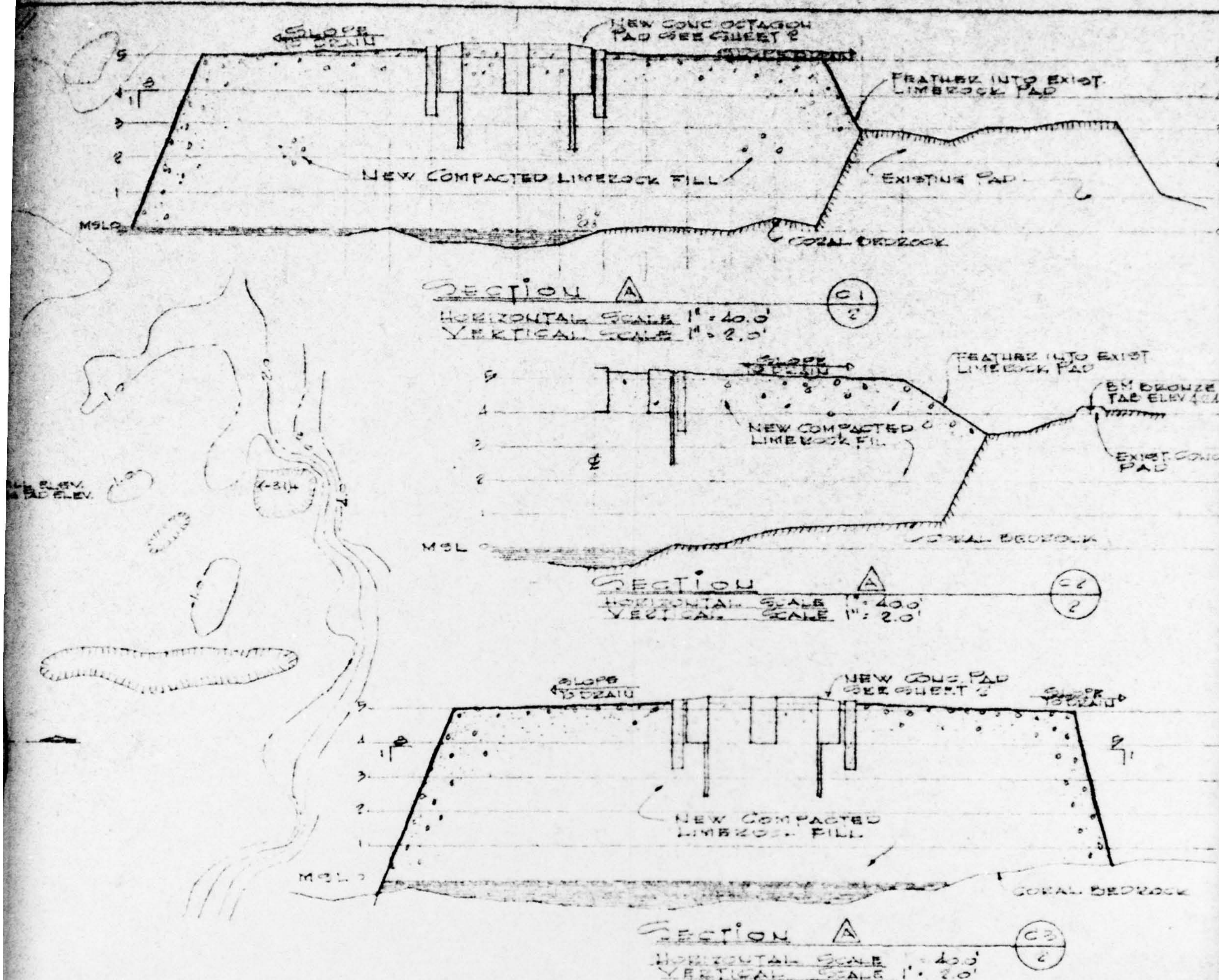

FIG. 4

LEGEND ON ELEVATION
1.0 EXISTING ELEVATION
[1.0] NEW FILL ELEV. FINISH GRADE

GROUNDING NOTE:

GROUNDING: NO. 2/0 BARE, SOFT-DRAWN COPPER WIRE DIRECT BURIED 18" BELOW GRADE SHALL BE USED FOR GROUND WIRE. CONNECTIONS TO STEEL PLATES BY THE GROUND WIRE AND SPLICES IN THE GROUND WIRE SHALL BE MADE BY EXOTHERMAL FUSION WELDING. SEA GROUNDING SHALL BE ACCOMPLISHED WITH A METALLIC ANODE,* FUSION WELDED TO GROUND WIRE, INSTALLED BELOW EXTREME LOW TIDE TO INSURE CONTINUOUS IMMERSION IN WATER. THE PORTION OF GROUND WIRE WHICH IS NORMALLY IMMERSED IN WATER SHALL BE INSULATED AND HAVE A POLYVINYL OR POLYCHLOROPRENE JACKET.

* DURCO ANODE TYPE J OR EQUAL

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	RANGE CONTRACTOR DATE	TELTA SOUTHERN BALLOON DEPLOYMENT SITE
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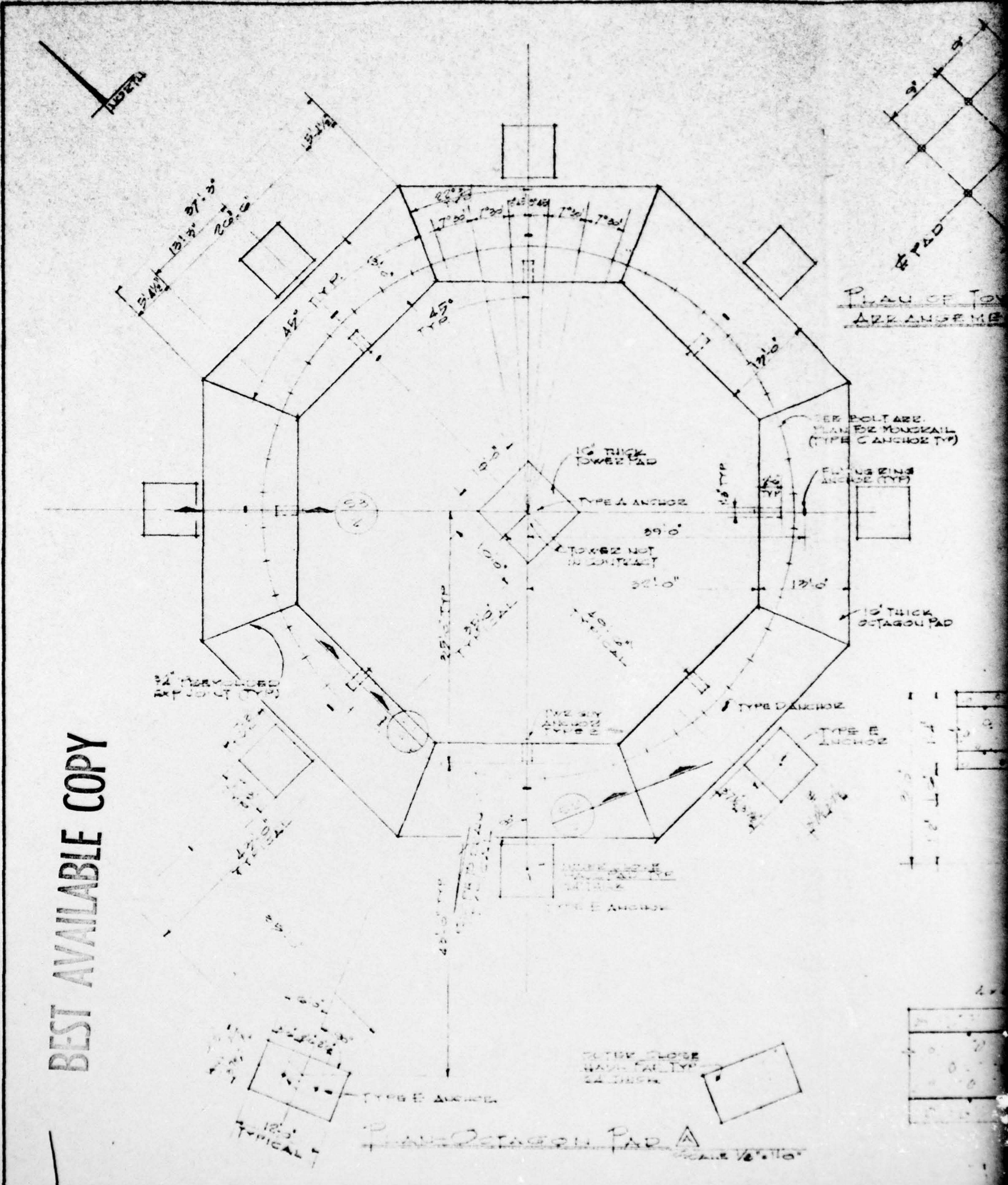

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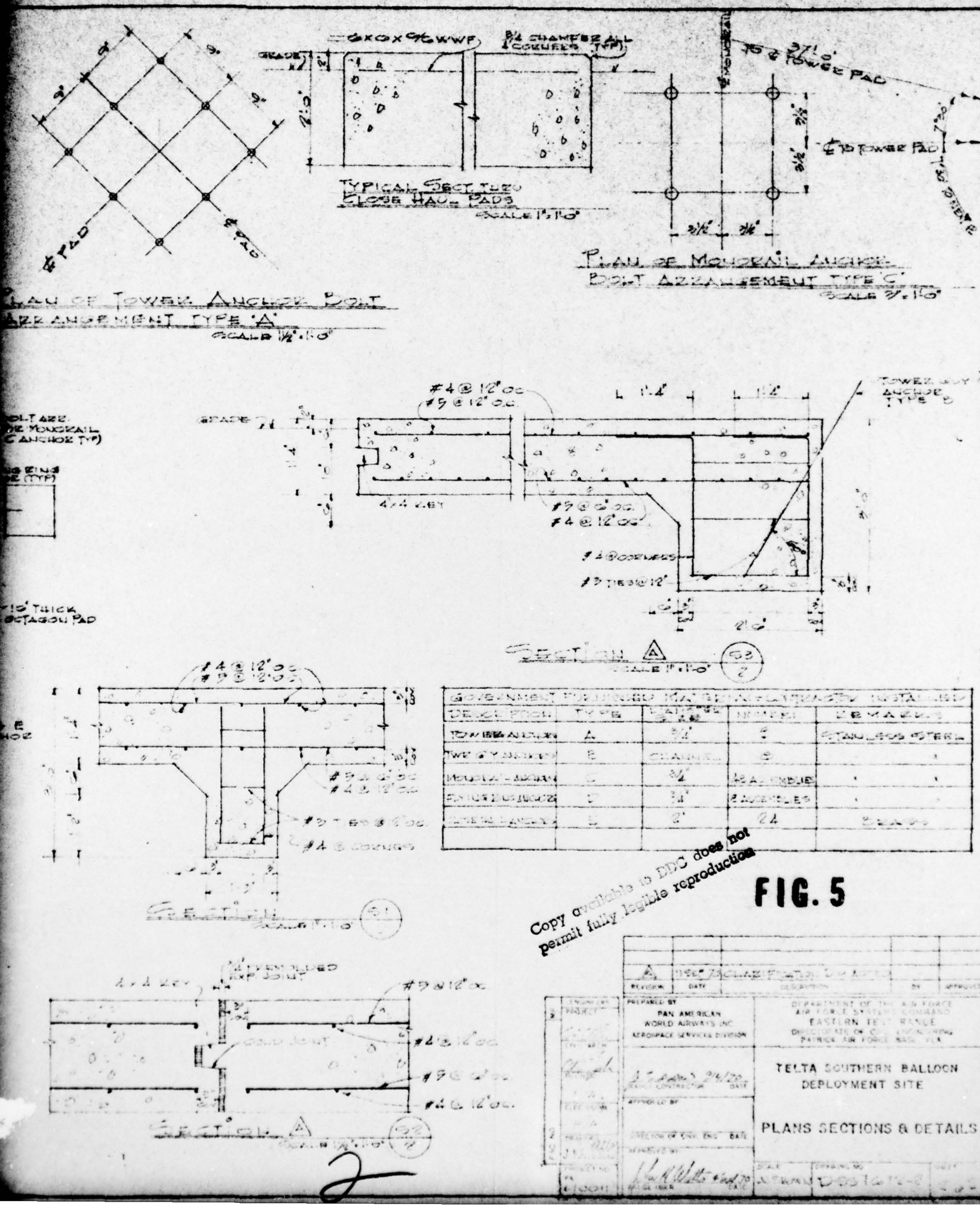

FIG. 5

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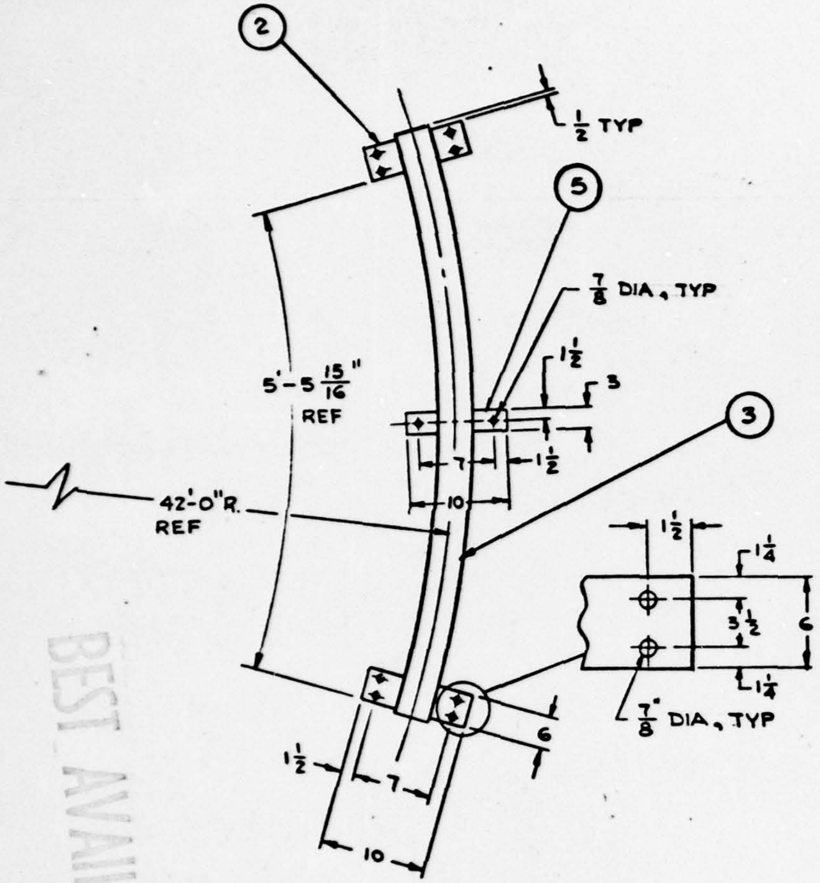
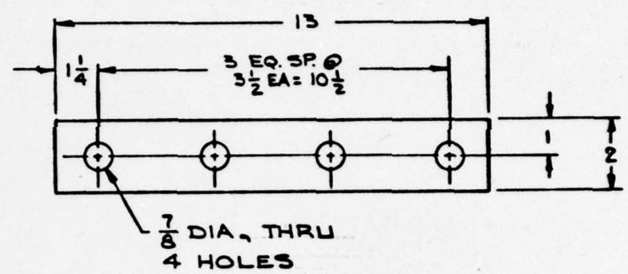
QTY	QTY	ITEM OR SYMBOL	DRAWING	PART OR GROUP	DESCRIPTION	MATERIAL
	48	1	THIS DWG-1		RAIL SECTION ASSY	
	96	2	THIS DWG-2		BAR, 6"X10"X$\frac{3}{4}$" THK MILD ST'L.	
	48	3	C-SK-5088-1		RAIL, 6"X3$\frac{3}{8}$"X12.5# AMER. STD. "I" BEAM	
	96	4	THIS DWG-4		BAR, 2"X13"X$\frac{1}{2}$" THK MILD ST'L.	
	48	5	THIS DWG-5		BAR, 3"X10"X$\frac{3}{4}$" THK MILD ST'L.	

LIST OF PARTS



① RAIL SECTION



④ BAR

NOTES:

1. REMOVE ALL BURRS & BREAK SHARP EDGES.

FIG. 6

DETAILS
MONORAIL FAMILY II MOORING
CUDJOE KEY

DRAWN BY [signature] 12-9-71 APPD K.K. [signature]
CHECKED BY KKW

PREPARED BY RCA INTERNATIONAL SERVICE CORPORATION FOR U.S. AIR FORCE EASTERN TEST RANGE PATRICK AIR FORCE BASE, FLORIDA

SCALE NONE

C-SK-5091

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2. Trolley Details

The design uses two, double-axle, Dresser "Budgit" trolleys as shown in Fig. 7. These units will be connected with a yoke bar, which, in turn, attaches at its center to the steel rope mooring painter. The trolleys are rated for 4000 pounds, each, working. Their working safety factor is 5. As a check, TELTA load-tested a 2000 pound trolley to 18,000 pounds without failure. The proposed arrangement would, by extrapolation, hold a 72,000 pound load.

B. Pad 3A Design

The design of the monorail for Pad 3A is the same as for Cudjoe Key except that the rail baseplates are bolted to the upper ends of anchors designed for this application. As noted above, these anchors will be imbedded in the compacted surface of the site by means of concrete, poured into the augered hole after setting the anchor. This is not a requirement for a quickly redeployable system where common "foundation anchors" will be used.

The use of hard, aluminum-alloy rails for the "portable" system is being studied prior to design release. The aluminum rail is feasible and will save about 50% in weight. The details awaiting resolution are the choices of alloy and of section-design to achieve the maximum strength-weight ratio.

VII. Mast Requirements

A most desirable feature of the monorail system is its independence of tower height, which may take any value of operational convenience and balloon geometry.

In the monorail systems contemplated for near term use in the TELTA program, the mast height presently in use, which permits the use of the mooring gondola and/or extant service vehicles, is the obvious choice.

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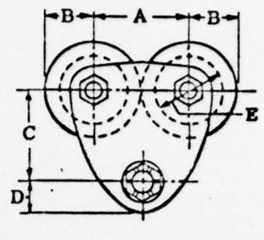

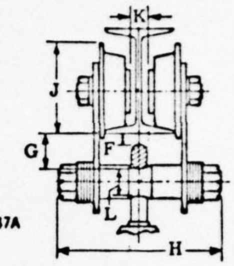

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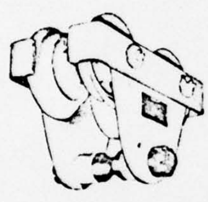
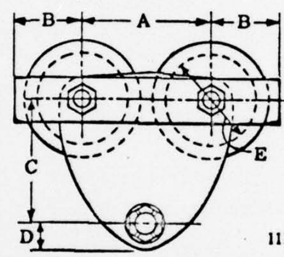
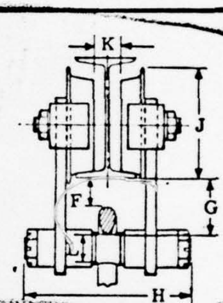
500, 1,000 and 2,000 POUND TROLLEYS

7424







11147B

4000 POUND TROLLEY

	TROLLEY CAPACITIES			
	500	1000	2000	4000
Catalog Number	80	81	82	83*
Net Weight (lbs.)	13	13	23	36
Beam Sizes (American Std. Section)	4" to 10"	4" to 10"	5"-12"	6"-18"
Minimum Radius Curve	2'-6"	2'-6"	3'-0"	4'-0"
OUTLINE DIMENSIONS (ins.)				
A	4 3/8	4 3/8	6 1/8	6 7/8
B	2 1/8	2 1/8	2 11/16	4 1/16
C	4 1/8	4 1/8	5	5 3/4
D	1 1/4	1 1/4	1 3/8	1 3/8
E	3 1/8	3 1/8	4	4 7/8
F Maximum**	15/16	15/16	15/16	7/8
G	1 7/8	1 7/8	2 1/4	2 3/8
H	7 7/8	7 7/8	8 7/8	10 1/4
J	3 15/16	3 15/16	4 7/8	6
K Minimum***	5/8	5/8	1 1/4	1 1/4
L	15/16	15/16	1 11/16	1 1/4

*Equipped with Bumpers.
**Dimension "F" is based on hook of standard BUDGIT Hoist, and smallest size beam on which trolley will operate. Dimension decreases slightly for each of the larger size beams.
***This Dimension (K) occurs on smallest size beam only. On larger sizes of beams it is increased by the difference in flange width.

BUDGIT MOTOR DRIVEN TROLLEY OPTIONS

Longer Than Standard Control Cable Lengths

Trolleys are equipped as standard with 7'-4" of P.B. Cable for standard 10' lift hoists. Available (at extra cost) only in 5' increments (up to 22'-4", for hoists with up to 25' lift). For greater lengths apply to factory.

Ballast Resistors

Ballast resistors may be ordered on trolley with three phase currents when cushioned starting is desired.

Electrical Adaptor Kits

The following are field conversion kits which are required when it is desired to modify existing Coil Chain Push Button Model BUDGIT Hoists for mounting on BUDGIT Motor Driven Trolleys.

Catalog No.	Electrical Current
901821	115 volt, 1 phase, 60 cycle A.C.
901822	230 volt, 1 phase, 60 cycle A.C.
901823	All voltages, 3 phase, 60 cycle A.C.

Current Collectors

When current collectors are to be used to supply power to trolley the following two types may be ordered with trolley at extra cost: Figure K, Spring Wheel Type for use with bare copper wire or bare figure "8" bar. Spring Slide Type for use with insulated figure "8" bar. Specify on order type and number of collectors required.

DRESSER

DRESSER CRANE, HOIST & TOWER DIVISION
DRESSER INDUSTRIES, INC.
MUSKEGON, MICHIGAN 49443

FIG. 7

BEST AVAILABLE COPY

VIII. Test Procedure for Monorail Mooring Checkout

The following list of events is a "first-cut" at identification of the actions required to operationally checkout a monorail mooring system.

Assumptions:

1. The balloon is inflated, rigged for flight, less only the windscreen, payload and fuel.

2. The mooring confluence lines are rigged as designed, for the BS 34.5 C-P, and the spreader plate and mooring painter are attached.

3. The balloon is closehauled and the noserope is attached, routed and ready for mating the tower to the balloon.

Docking and Mooring Balloon:

1. Attach an 8" combination sheave to the trolley yoke-bar with a shackle.

2. Run a 1 inch line from the confluence point eye, (same eye as used for painter) through the sheave, to a tow vehicle.

3. Pull the balloon into the tower, pull down on the C-P, and relax the closehaul lines.

4. When the balloon latches, continue to pull down the C-P until the painter can be connected.

5. With painter connected, relax tow on C-P line and remove. Balloon is moored.

Checking Forces:

1. Using the C-P handling line in prior operation, install tension scale between trolley-yoke and C-P. Measure tension.

2. Measure balloon "up" force by pulling down on nose probe with line and scale. It should be possible to see (from the "high-ranger") when the downward pull <u>just</u> takes up the "play" in the latch mechanism. The value of tension on the scale at this point is the balloon "up" force.

If the tower height and tail clearance are acceptable, and the mooring angle is as desired, the confluence lines should be trimmed so as to produce the desired nose force on the tower. The achievment of satisfactory values for these parameters signifies a correctly moored balloon.

IX. Cost and Schedule Information

A. Cudjoe Key Site

Rail 16 - 20 ft. lengths, 6" "I" (12.5)	4,000 lbs.
6 - 20 ft. lengths, 1/2" X 2"	408
48 rng.ft. 3/4" X 3"	367
96 rng.ft. 3/4" X 6"	1,469
Trolley Yoke 2ft^2 X 1/2" plate	41
	6,285 lbs.
steel @ $0.10/#	$628.50
2 #83, 4K# trolleys @ $65.50	131.00
480 Red Heads @ $70.30/c	337.44
480 CRES lockwashers @ $124.10/m	59.57
384 3/4" - 10 X 2½" CRES bolts	402.43
96 3/4 - 10 X 2" CRES bolts	95.64
Total Material:	$1,654.58
Rolling rail @ $0.15/lb. X 4000	$600.00
Shear & punch rail bars	336.60
Fab trolley yoke	100.00
Sink Red Heads; fasten rail (200 H)	960.00
Welding; 24 hr. @ $10.00	240.00
Total Labor:	$2,236.00
Total Labor and Material:	$3,891.18

Schedule: 21 days after total commitment

B. Pad 3A Site

Rail	16 - 20 ft, 6" "I" (12.5)	4,000 lbs.
	6 - 20 ft. 1/2" X 2"	408
	48 rng.ft. 3/4" X 3"	367
	96 rng.ft. 3/4" X 6"	1,469
Trolley Yoke	2ft^2 X 1/2"	41
		6,285 lbs.
	steel @ $0.10/#	$628.50

96 Anchors (SS) $1\frac{1}{2}$" dia. 6'0", 40#ea;	3840#
96 Plate (SS) 12" X 12" X 1/2	1920#
192 Plate (SS) 12" X 6" X 1/2	1920#
	7,680 lbs.

Stainless Steel @ $1.00/#	$7,680.00
2 #83 4K# trolleys @ $65.50	131.00
Bolts & Nuts (SS) 3/4"	560.00
Total Material:	$8,999.50
Roll rail, shear & punch plates, fab plate	$1,000.00
Fab anchors	1,500.00
Anchor Setting	1,000.00
Total Labor:	$3,500.00
Total Labor & Material:	$12,499.50

Schedule: 25 days after total commitment

C. Comments on Cost and Schedule

The installation labor at Cudjoe Key may be performed by PAA/TELTA. If so, the cost of this work is indirect.

All major material including trolleys is available, ex-stock from nearby suppliers (ORL & ATL).

Stainless steel was used for Pad 3A anchors because of the salt environment and the proposed permanence of the site.

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E.L.C. 11-09-71

APPENDIX 'A'

Summary of Stress Calculations on Monorail

3600 lbs. nominal lift of balloon

Cudjoe Key Anchor Bolts

3/4" - 10 NC threaded rod - Root area 0.3091 in.
yield strength = 35,000 psi

Yield load per anchor bolt:
= 35,000 X 0.3091 = 10,819 lbs.

Each rail section held by four bolts
total load = 4 X 10.819 = 43,276 lbs.

$$F.S. = \frac{43,276}{3,600} = 12.02 \text{ based on nominal lift.}$$

Monorail Sections

For worst case bending, assume load concentrated at center of 51" span.

$$\text{Bending stress } (f_b) = \frac{M}{S}$$

f_b = 36,000 psi, yield

S = 7.3 in^3 for 6"I 12.5

$M = f_b \times S$ = 36,000 × 7.3 = 262,800 in - lbs.

$$\text{Load} = \frac{4 \times M}{\text{Span}} = \frac{4 \times 262,800}{51} = 20,612 \text{ lbs.}$$

$$F.S. = \frac{20,612}{3,600} = 5.73 \text{ based on nominal lift}$$

"Budgit" Trolley, 4,000 lbs. capacity

For 2 trolleys capacity = 8,000 lbs.

F.S. 5 on ultimate

Failure load = 5 x 8,000 = 40,000 lbs

F.S. = $\frac{40,000}{3,600}$ = 11.11 based on nominal lift

For CKAFS Anchors with 1½" dia. 303 CRES Bar

Yield strength = 35,000 psi

Area = $\frac{\pi}{4}(1.5)^2$ = 1.7672 in^2

Yield load on anchor = 1.7672 x 35,000 = 61,852 lbs

F.S. = $\frac{61,852}{3,600}$ = 17.18 based on nominal lift

Anchor should develop not less than 20,000 lb. pull out strength.

F.S. $\frac{20,000}{3,600}$ = 5.56 based on nominal lift.